NATIONAL TRANSPORTATION SAFETY BOARD
Office of Research and Engineering
Washington, DC

January 31, 2000

ADDENDUM I TO MAIN WRECKAGE FLIGHT PATH STUDY

By Dennis Crider

A. ACCIDENT: DCA-96-MA-070

Location: East Moriches, New York
Date: July 17, 1996
Time: 2031 Eastern Daylight Time
Airplane: Boeing 747-131, N93119

B. GROUP IDENTIFICATION

No group was formed for this activity.

C. SUMMARY

On July 17, 1996, at 2031 EDT, a Boeing 747-131, N93119, crashed into the Atlantic Ocean, about 8 miles south of East Moriches, New York, after taking off from John F. Kennedy International Airport (JFK). The airplane was being operated on an instrument flight rules (IFR) flight plan under the provisions of Title 14, Code of Federal Regulation (CFR), Part 121, on a regularly scheduled flight to Charles De Gaulle International Airport (CDG), Paris, France, as Trans World Airlines (TWA) Flight 800. The airplane was destroyed by explosion, fire, and impact forces with the ocean. All 230 people aboard were killed.

D. DETAILS OF THE INVESTIGATION

PURPOSE OF ADDENDUM

The Main Wreckage Flight Path Study developed the flight paths of the aircraft from the departure of the forward portion of the fuselage to the ocean floor. The flight paths were developed using a simulation that used estimates of the change in 747-100 aerodynamic coefficients with the forward fuselage removed. This addendum provides results of a sensitivity study that examined the effect of uncertainty in these aerodynamic changes on the flight path of the aircraft.

The Main Wreckage Flight Path Study mentioned, but did not quantify, the uncertainty in the radar data. Since the original report, a program (RADARBOX) has been developed, which can define the geometry of radar uncertainty boxes. This program has been used to define these boxes for comparison with the simulations. The original report used a composite of primary radar returns from all sites. This addendum addresses each radar site separately.

RADAR UNCERTAINTY

A radar station determines the position of a target based on the range to the target (determined by timing the return of the radar pulse) and the angle between North and the target which is referred to as azimuth. The Radar stations that tracked TWA 800 define the azimuth angle with 4096 azimuth change pulses (ACP). Thus, the area around the antenna is divided into 4096 pie shaped regions with the antenna in the center. Azimuth is therefore recorded at a resolution of +/- 1/2 ACP. The FAA reports range accuracy for these radars as +/- 1/16 Nautical Mile.

The program RADARBOX was run using the range[1] and azimuth from the Islip (ISP), JFK airport (JFK) and Whiteplains (HPN) radar sites that recorded primary radar tracks between the last secondary return and the main wreckage recovery point. The radar returns from these radars and the main wreckage recovery location are plotted in figure 1. These radar returns are plotted as a function of time in figures 2 and 3. As can be seen in these plots, the beacon returns from each radar site describe a band ¼ to ½ Nmi wide. Point to point within a secondary radar track however, the data appears consistent with the given accuracy.

---

[1] Since altitude information was not available for these primary returns, an altitude of 10000 ft was in the conversion from recorded slant range to ground range. This value represents a rough average altitude for the period of crippled flight. The maximum difference between slant range and ground range was 0.07 NM.

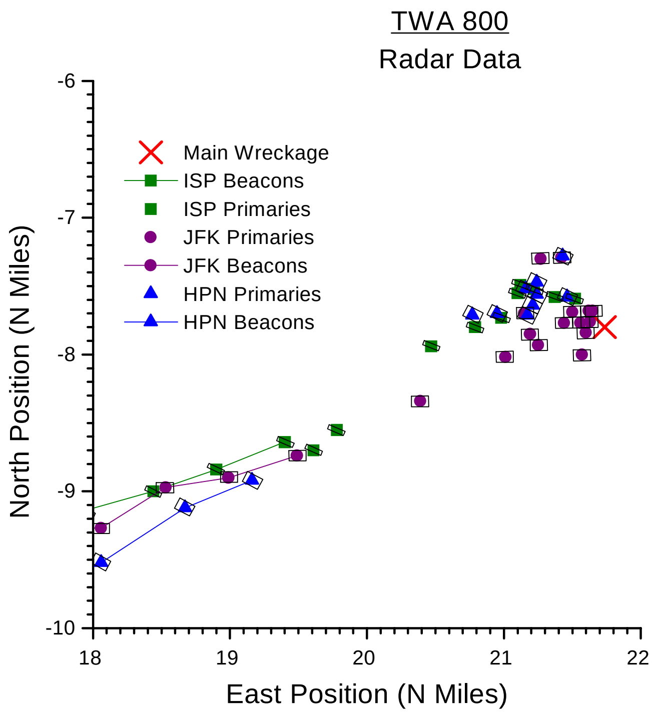

Figure 1; Radar Map View

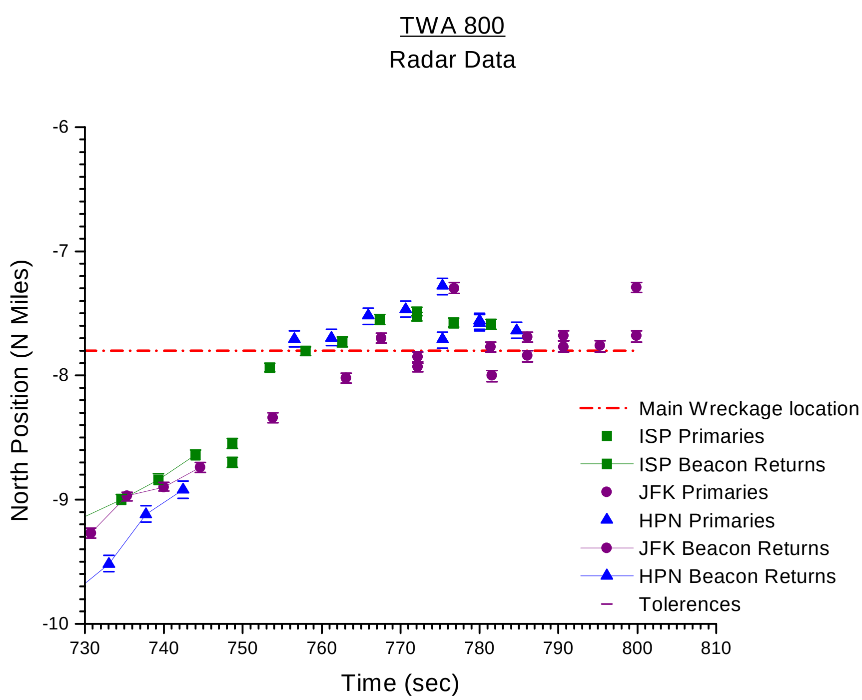

Figure 2; Radar North vs. time

TWA 800
Radar Data

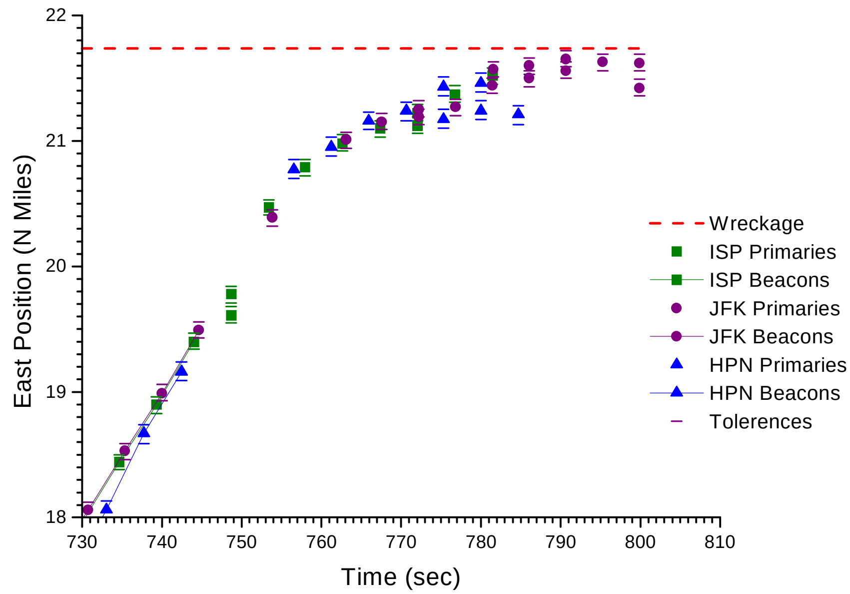

Figure 3; Radar East vs. Time

Additional factors come into play for the primary returns with an in-flight breakup. For example, changes in return strength as wreckage changes orientation relative to the radar may introduce errors. Examination of figures 2 and 3 shows incidences of multiple returns for several times.

AERODYNAMIC UNCERTAINTY

Boeing estimated the longitudinal aerodynamic characteristics (lift, drag and pitching moment) for a 747-100 without the forward fuselage. With current technology it was not possible to estimate these characteristics with precision, particularly at high angle of attack. Accordingly, Boeing has established a range of values for these coefficients at 30 degrees angle of attack. These are 1.0 to 1.4 for lift coefficient, 0.5 to 1.0 for drag coefficient and –0.6 to –1.4 for pitching moment coefficient.

SIMULATION RESULTS

Rather than develop a simulation for all combinations of aerodynamic tolerances, a range of effects was established using a combination of tolerances to establish a “fast” and “slow” simulation. The “fast” simulation consists of the maximum nose down aerodynamic pitching moment coupled with minimum drag and lift. The “slow” simulation consists of the minimum nose down aerodynamic pitching moment coupled with maximum drag and lift.

As described in the original study, tilting the lift vector maneuvered the simulation. All parameters and procedures not mentioned in this addendum remained unchanged from the original report. A simulation was run emphasizing each of the radar sets for a slow, nominal and fast aerodynamics simulation. The results for the slow simulation are presented in figures 4 to 8.

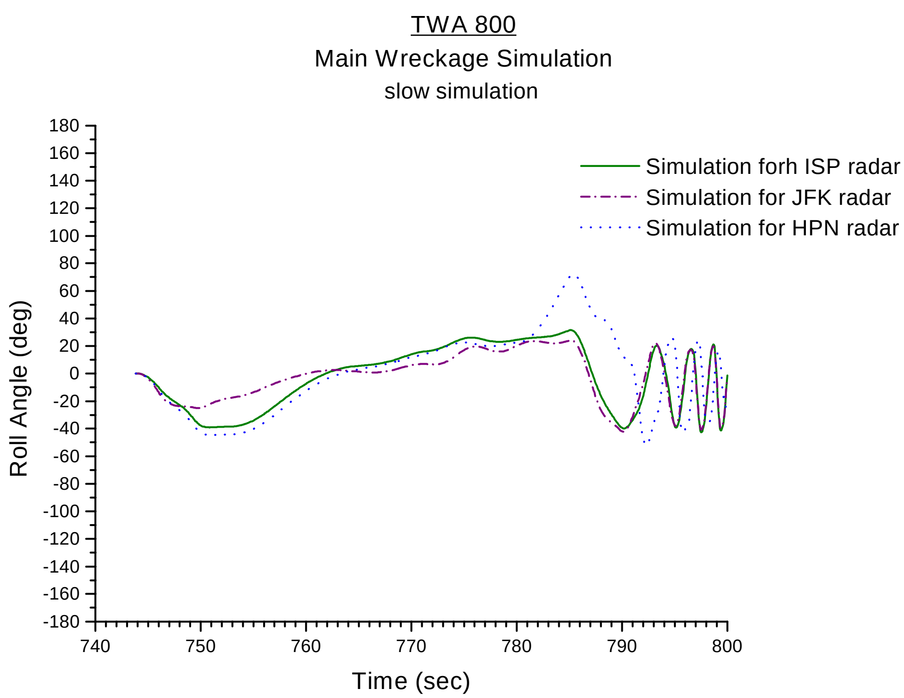

Figure 4; Roll angles for slow simulations

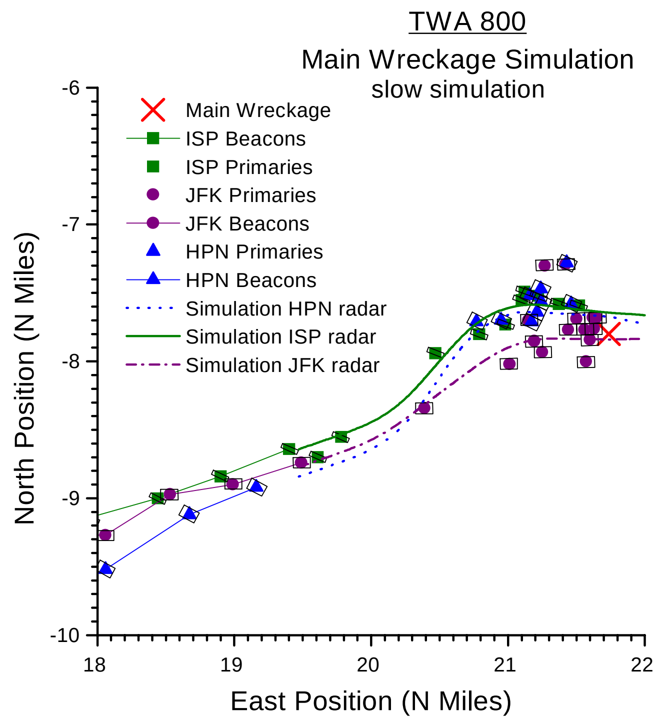

Figure 5; Map view of slow simulations

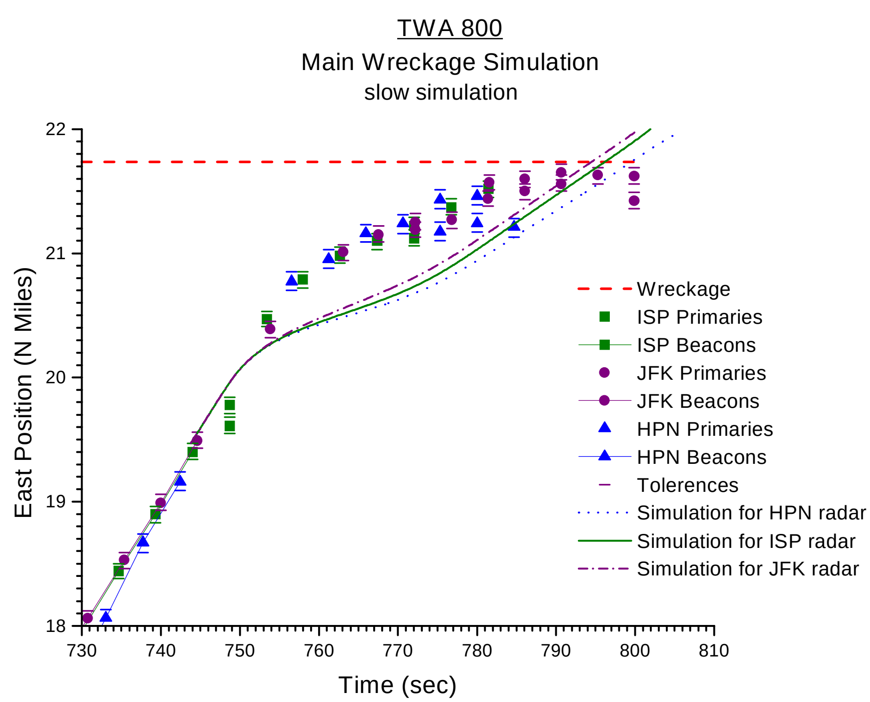

Figure 6; East positions for slow simulations

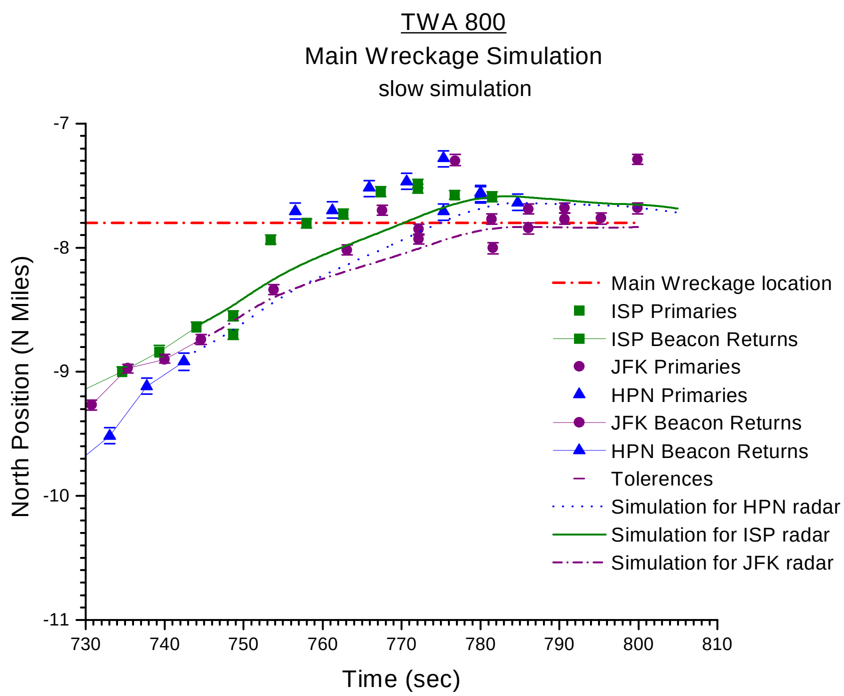

Figure 7; North positions for slow simulations

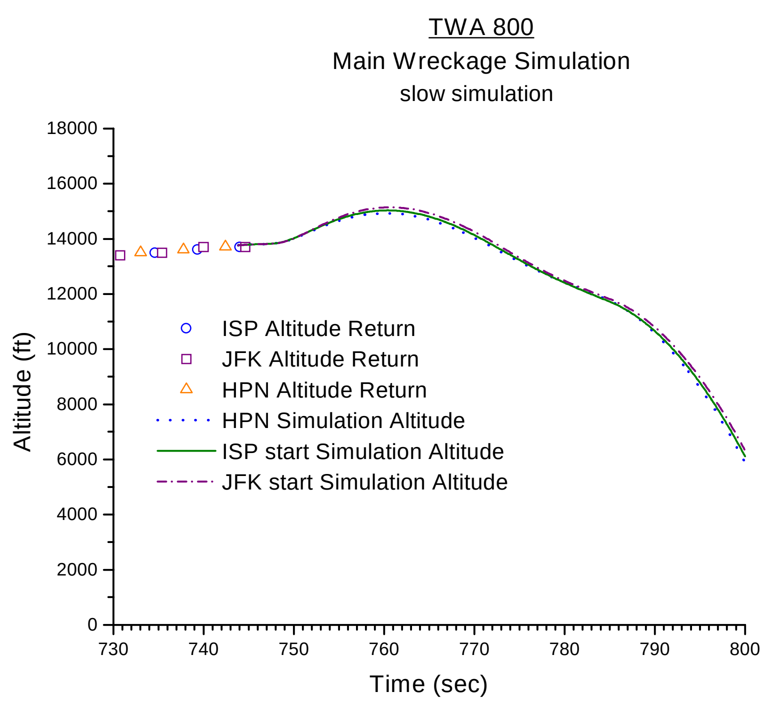

Figure 8; Altitude for slow simulations

As can be seen from the East vs. time plot in figure 6, the slow simulations for all the radars are outside the radar band for the event. The results for the nominal simulation are presented in figures 9 to 13.

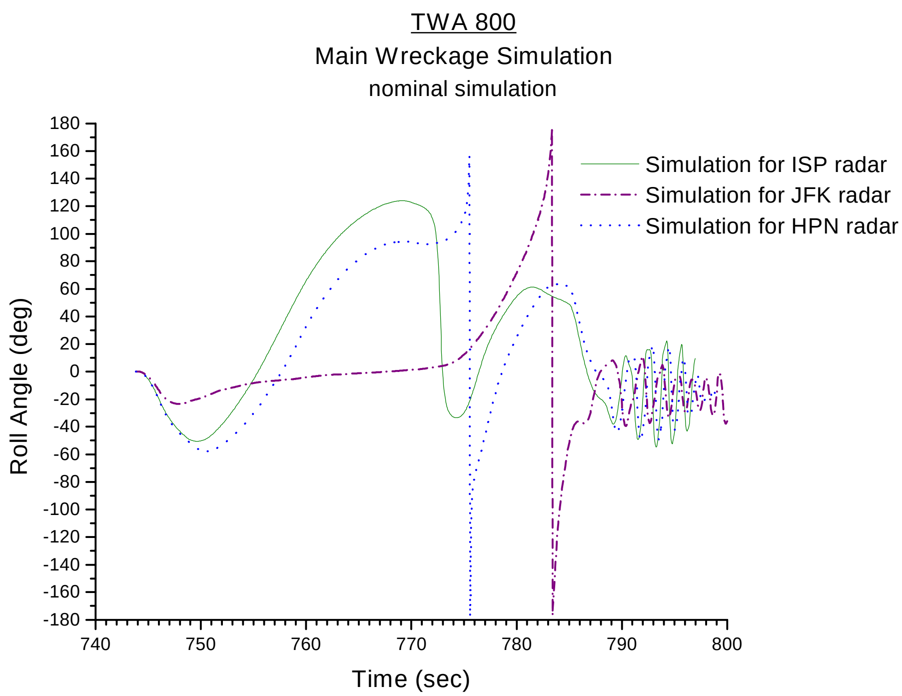

Figure 9; Roll angles for nominal simulations

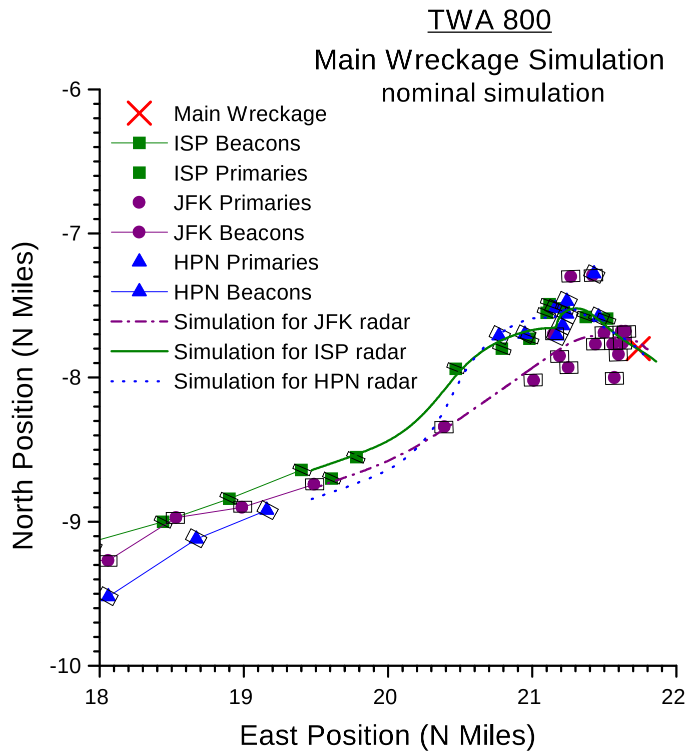

Figure 10; Map View of nominal simulations

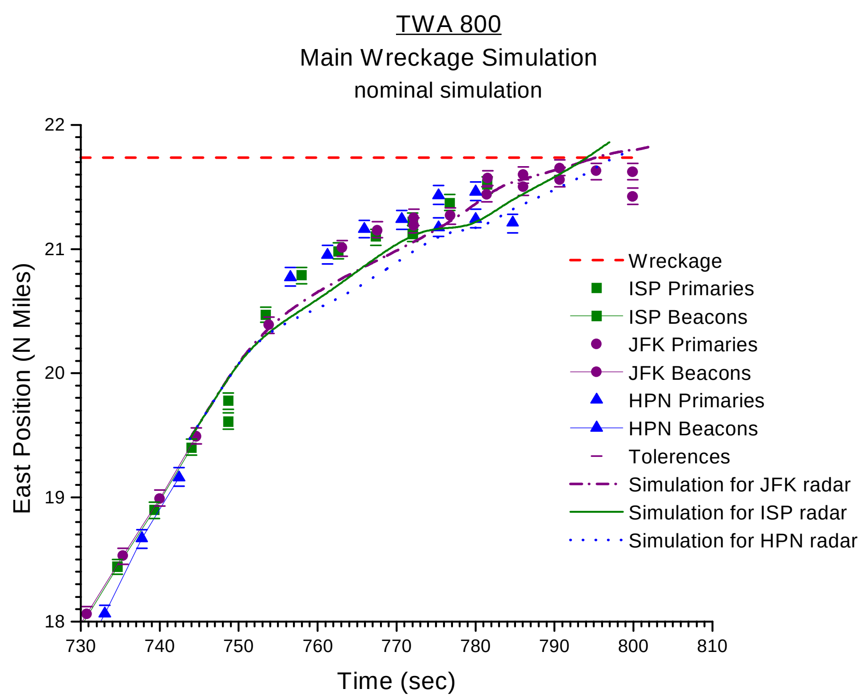

Figure 11; East Positions for nominal simulations

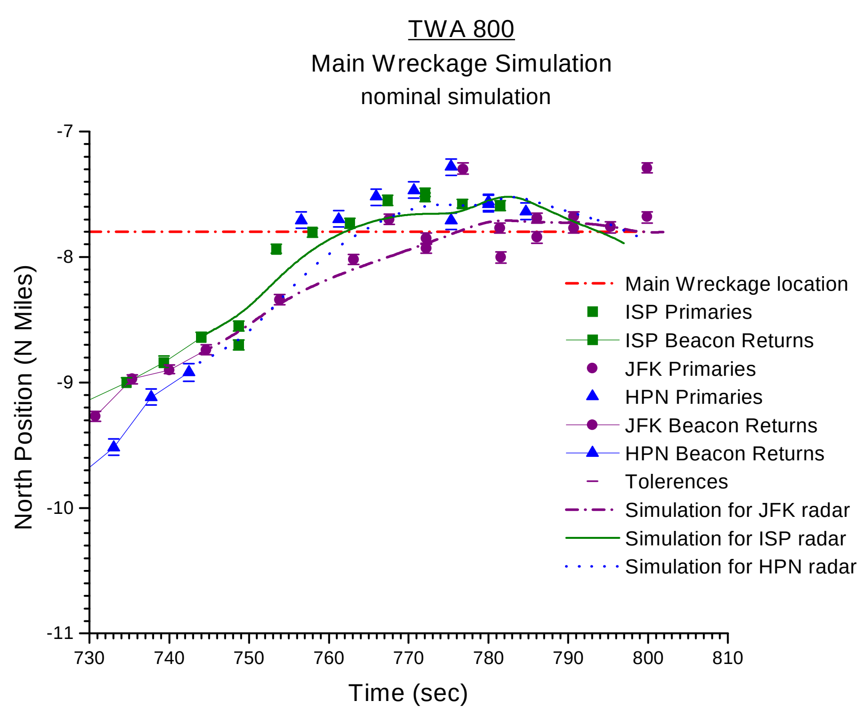

Figure 12; North positions for nominal simulations

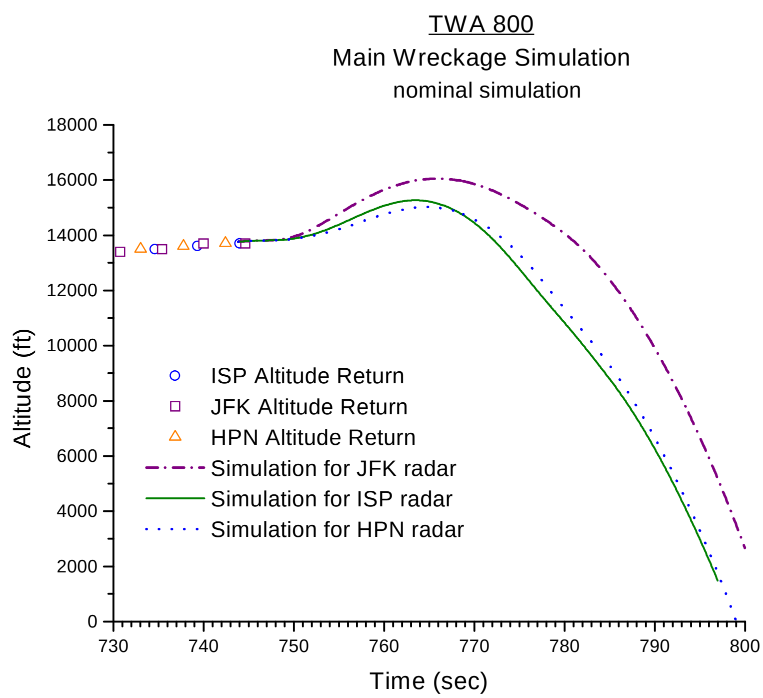

Figure 13; Altitudes for nominal simulations

As can be seen from the East vs. time plot in figure 11, the nominal simulations for all radars are outside the radar tolerance in the region between approximately 755 and 770.

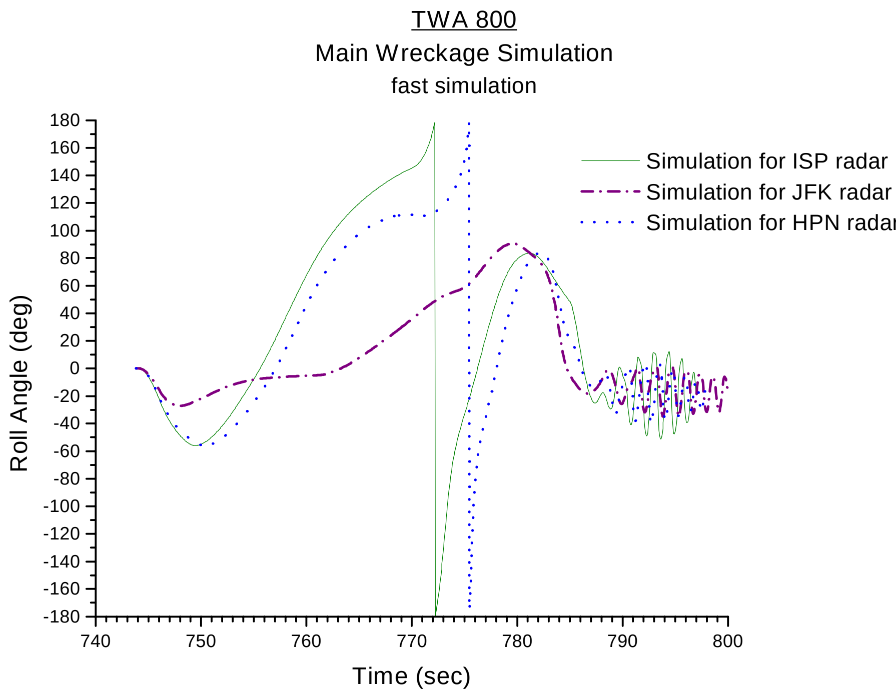

Figure 14; Roll angles for fast simulations

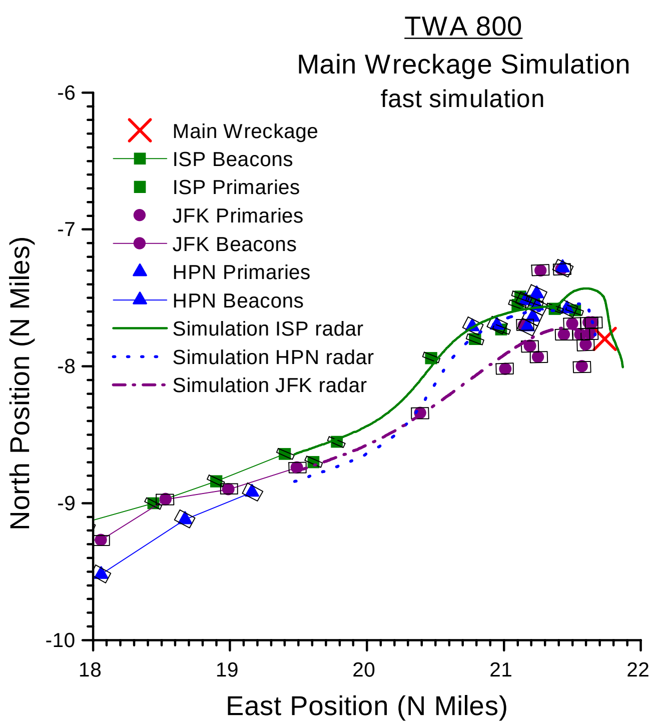

Figure 15; Map view of for fast simulations

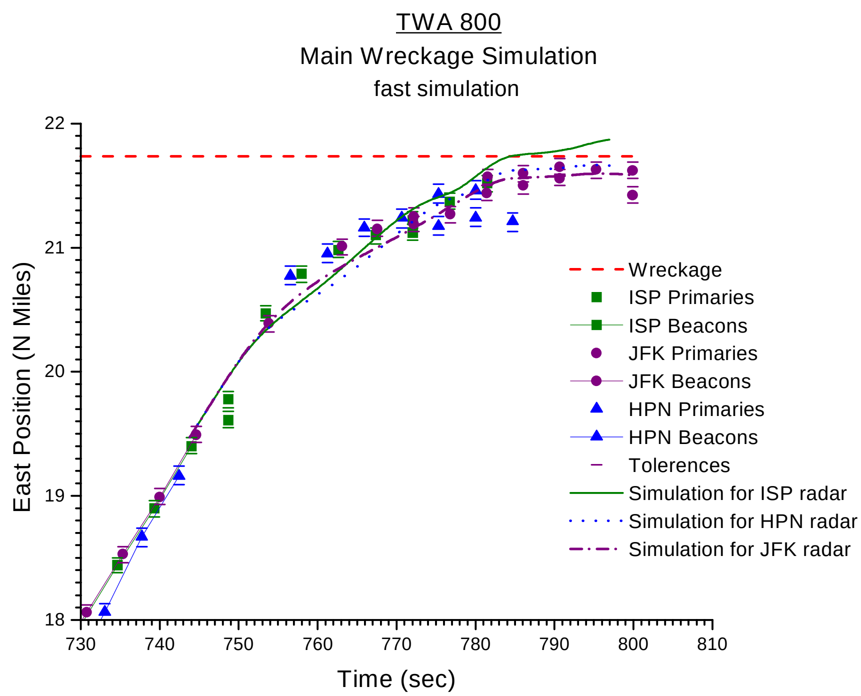

Figure 16; East positions for fast simulations

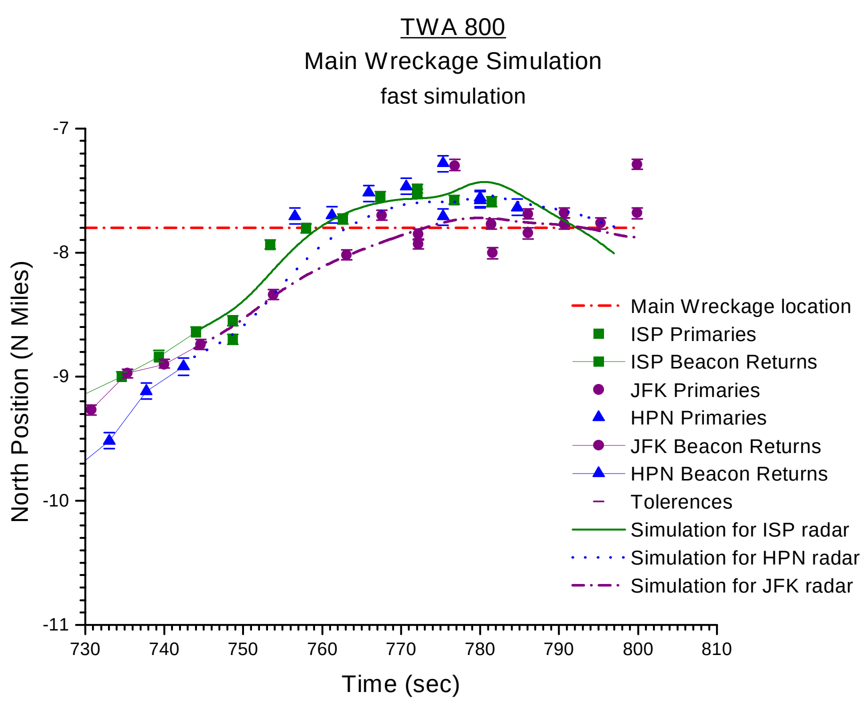

Figure 17; North positions for fast simulations

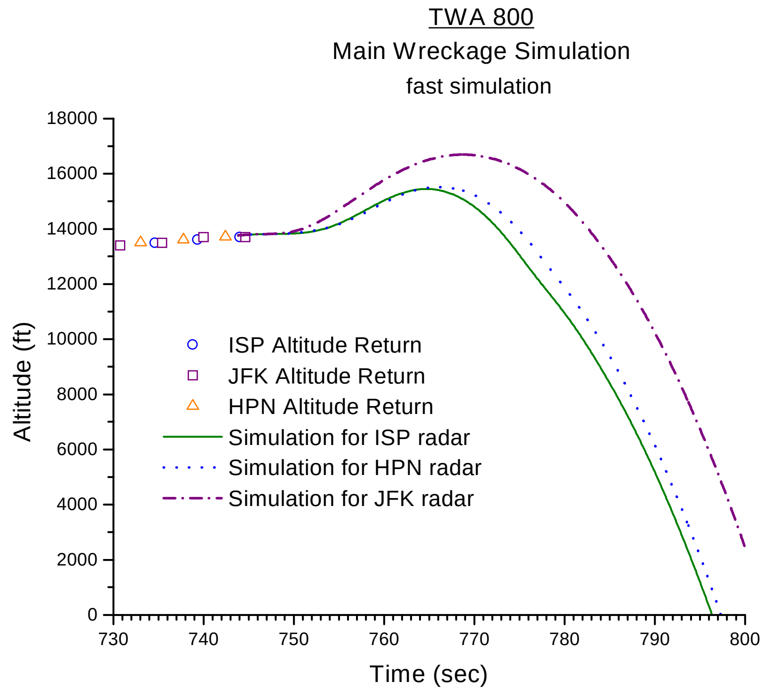

Figure 18; Altitudes for fast simulations

As shown in figure 15, the fast simulations flew very close to the radar points.

EFFECT OF NOSE SEPARATION TIMING

The trajectory study indicated that there is a four-second interval during which the nose could have departed. The simulations in the original report and in this addendum have used a nose departure time at the beginning of this interval. Simulations with a nose departure at the end of the four-second interval did not match the radar. Simulations with a nose departure in the middle of the four-second interval did not match the radar when trying to fly through the Northern most radar points (ISP and HPN). A nominal simulation was found however, that flew very close to the JFK radar data tolerances, including it's small initial left turn with the nose departure in the middle of the four second interval. This is shown in figures 19 to 23.

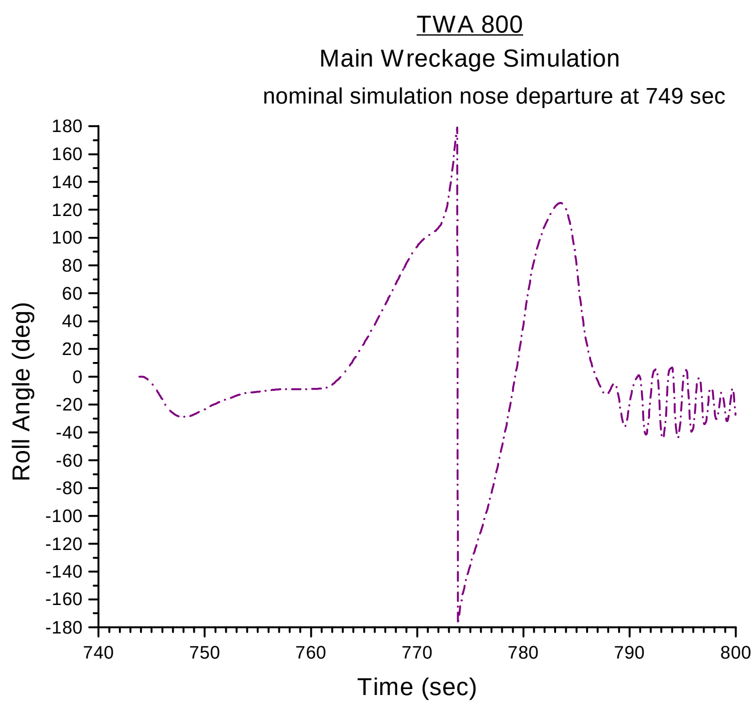

Figure 19; Roll angle for nose off at 749 sec

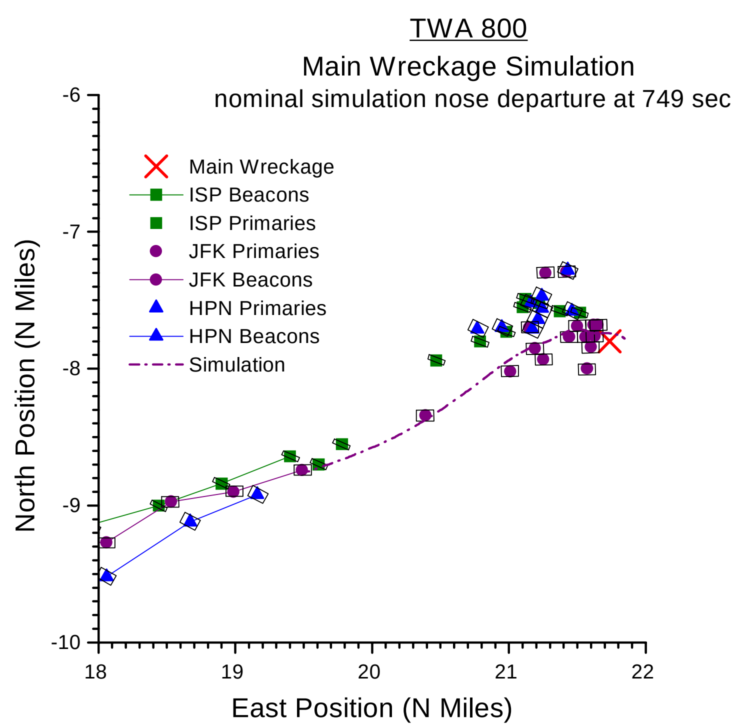

Figure 20; Map view of nose off at 749 sec sim

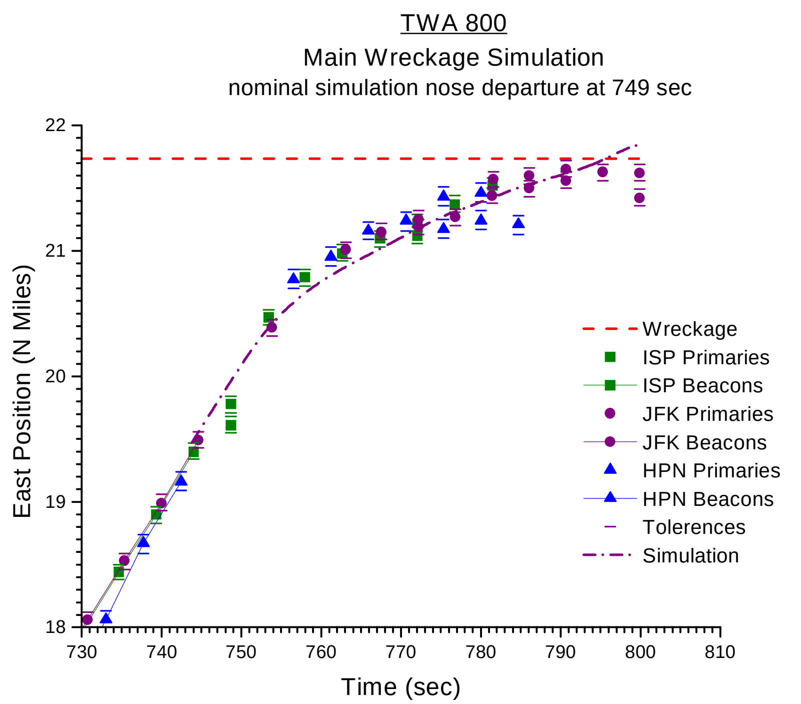

Figure 21; East position for nose off at 749 sec sim

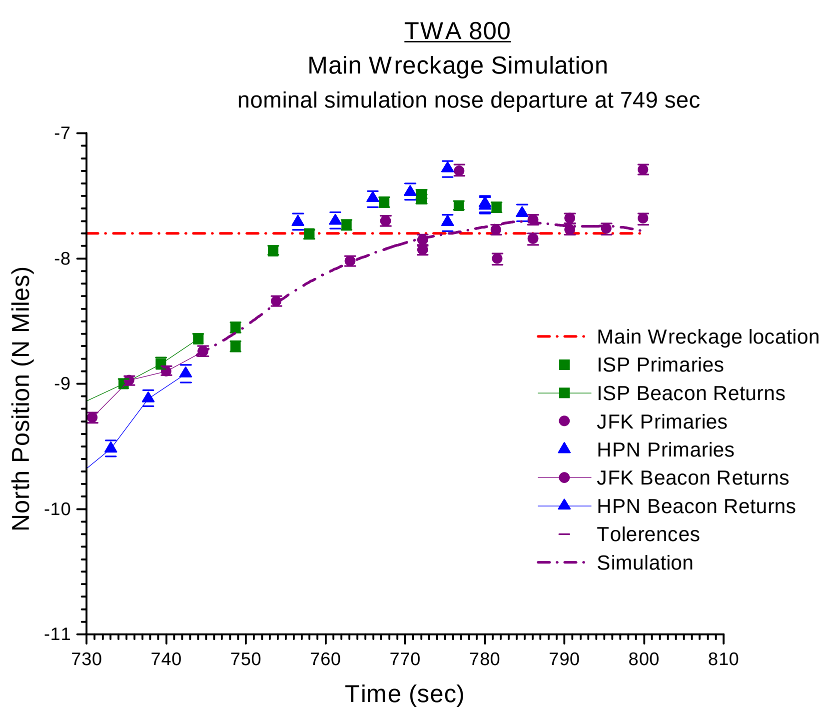

Figure 22; North position for nose off at 749 sec sim

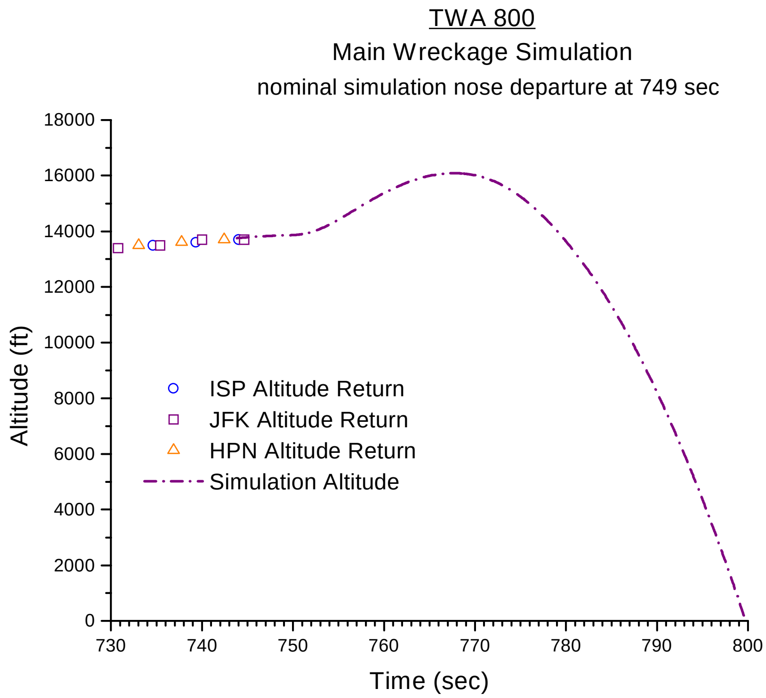

Figure 23; Altitude for nose off at 749 sec sim

SUMMARY

Individual radar returns from Whiteplains, JFK and Islip radar sites have been plotted for comparison with simulation results. The effect of aerodynamic uncertainty for a nose-less 747-100 has been explored.

The departure of the nose shifts the center of gravity aft causes a nose up pitching moment. As established in the original report, the pure longitudinal response of the aircraft to the loss of the nose would be a pitch up to a dynamic climb (zoom) as airspeed rapidly bleeds off. The extent of this climb is reduced by a turn to the North. Radar limitations during an in-flight breakup create uncertainties in the altitude gain. This report has identified maximum altitudes from 14926 ft to 16689 ft.

[original signed]

Dennis Crider
Aerospace Engineer Performance